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Experimental investigation of coating degradation during simultaneous acid and erosive particle exposure

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Abstract

When used in industrial processes, such as stirred acid leaching in the mineral industry, thermoset coatings are exposed to a combination of aggressive chemicals and erosive particle wear. While each exposure condition has been studied separately, no research has been presented on the effects of a simultaneous exposure. To investigate this, a pilot-scale stirred acid leaching tank, containing erosive particles and acidic solutions, has been designed and constructed. Resin types considered are amine-cured novolac epoxy and vinyl ester. Transient coating degradation is mapped through visual inspection and changes in film thickness. The new set-up, capable of experimenting with erosive particles in acidic solutions, is presented. In addition, results from preliminary experiments, using abrasive particles and water in a high-speed disperser, are discussed.

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Introduction

Thermoset resins have been used in acidic environments since the 1950s and have a track record as resistant materials for operations such as flue gas desulphuriaztion plants and similar acidic environments [1–3]. The mechanisms of erosive wear of polymers and composites have previously been described [4]. However, no research on coatings in situations when both exposure conditions are present simultaneously has been found. Such an environment can be encountered in agitated leaching of copper ore particles, a vital process in copper extraction and refining that utilizes diluted sulphuric acid to dissolve copper minerals, separating the metal from other unwanted insoluble materials. The process involves ground particle matter in a heated (75 °C) and stirred tank reactor, with a liquid pH below 1.0. Typical practice for testing of coatings in such environments includes separate immersion and erosion experiments, and do not take into consideration the combined effect. A pilot-scale leaching reactor has been designed and constructed to allow a transient analysis of the degradation process. The set-up is a downscaling of a full-scale leaching reactor, capable of exposing coating samples to simultaneous chemical and erosive stress. The data repeatability of the set-up is investigated through short (3 days) and long term (30 days) experiments. The effects of lowering the solution pH on coating performance is also studied.

Experimental

The pilot-scale reactor simulates the conditions found in stirred copper leaching reactors and is a downscaling of a selected full-scale leaching reactor. To ensure the same flow pattern, the geometrical relations are maintained for the reactor, baffles and impeller systems. The stirring intensity, power input per liquid volume [W/m^3], is maintained and particle concentration is also kept the same in pilot and full-scale. The stirring required to achieve complete particle suspension in the pilot reactor was calculated according to the Zwietering's correlation [5], and was found not to be in conflict with the requirement of maintaining stirring intensity. Figure 1 shows the reactor and baffle system as well as the impellers and the copper rich ore used for experimentation.

Figure 1: *Top: The pilot-scale reactor, internal diameter of 400 mm and removable baffle system. Bottom left: Double impellers on mixer shaft. Bottom right: Copper rich ore (erosive particles) used in acid leaching tanks. The mean spherical volume diameter of the particles is 44.9 μm.*

The two coating resins used are an amine-cured novolac epoxy and a vinyl ester. Both coatings were post cured at 60 °C for 2 days.

Experiments were performed in both water and sulphuric acid solutions. For water experiments, distilled water mixed with 20 wt.% copper ore was used. For acid experiments, 0.15 M sulphuric acid mixed with 20 wt.% copper ore was used. In both experiments, liquid temperatures were maintained at 75 °C.

Changes in dry film thickness (DFT) of coatings placed on the sides and bottom of the reactor are important for monitoring the erosion process. Coating thickness measurements were taken using a non-destructive electromagnetic induction coating thickness gauge (Elcometer 355, with an accuracy of ±1%).

Preliminary investigations, using a high speed disperser, to investigate the particle erosion of novolac epoxy coating in water have also been performed. Experiments were conducted on a metal container with internally coated sides and bottom. The coating was exposed to the abrasive flow of particles from the stirring action of the bottom mixing impeller at 500 rpm, placed 10 cm above the container bottom.

Results and Discussion

At present, only results from the high speed disperser with erosive particles are available. At the conference, results with simultaneous acid and erosive particle exposure in the pilot plant set-up will be presented.

In the high speed disperser, no measurable or visible erosion occurred on the coated container sides, thus only the wear of the bottom coating is shown. Figure 2 shows the coating on the container bottom, where the surface has been coloured with blue lines to investigate the erosion pattern. The figure shows an abrasive pattern with rotational symmetry, where erosion severity is a function of distance from the center point. The erosive damage is most severe below the outer part of the impeller blades and fades out towards the center and edge of the coated area.

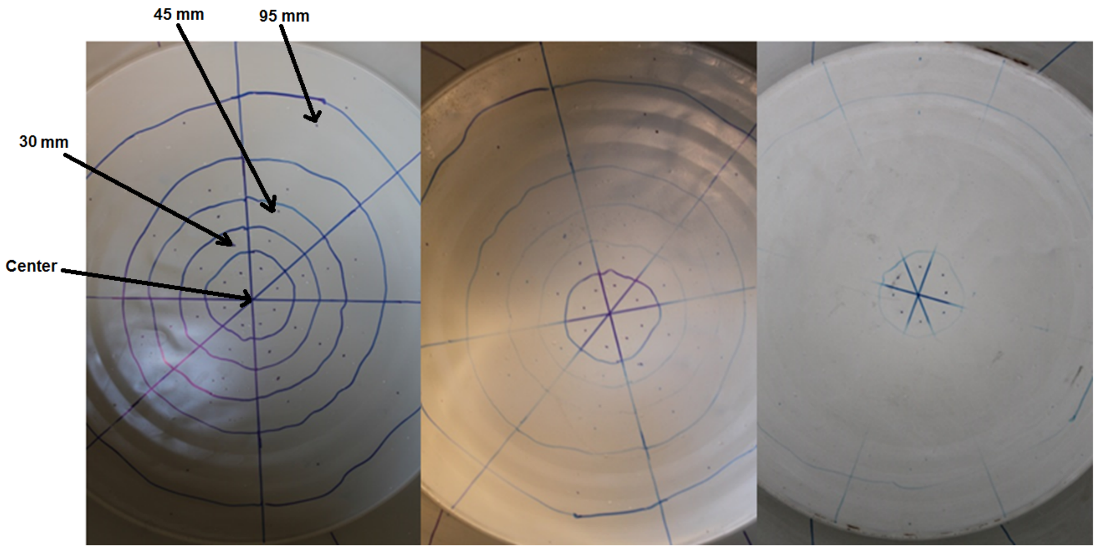

Figure 2: *Symmetric erosion pattern observed on container bottom coating after: 0 h (left), 34 h (middle) and 180 h (right) exposure time. The container diameter is 250 mm, arrows indicate distances from container center.*

Assuming rotational symmetry, the loss of film thickness was monitored at selected distances from the center. Two results are shown in Figure 3. The film thickness is seen to increase initially, after which the thickness decreases steadily. Assuming a linear decrease in the erosion dominated region, gives average slopes of -0.057 and -0.085 $\mu m/h$ for 0 and 45 mm distances from the center, respectively. Extrapolating, this yields an approximate lifetime of 2.4 years for a typical 1800 μm coating [6], assuming erosion is the only failure mechanism.

Conclusions

A new pilot-plant, for experiments with simultaneous acid and erosive particle exposure, has been constructed. Preliminary investigations using a high speed disperser have been performed.

For experiments using the high speed disperser, the visual observations of the erosion patterns and coating DFT measurements showed that damage due to erosive forces in mixing containers

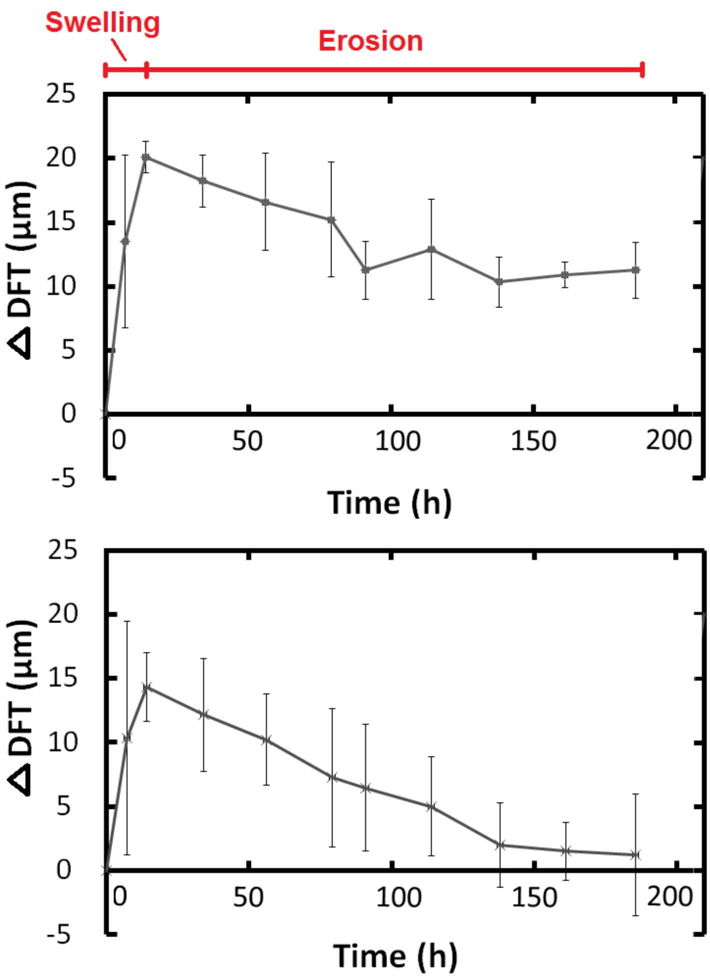

Figure 3: *Transient changes in film thickness relative to a nominal thickness of 0 μm. Top plot is at 0 mm and bottom plot at 45 mm distance from center. The initial rise is caused by swelling, and the subsequent decrease by particle erosion.*

are most severe at the bottom of the container. Visual observations also indicate that the erosion severity changes as a function of distance from the container center, with the most significant erosion observed below the outer parts of the impeller blades.

Changes in DFT are a function of swelling, caused by water diffusing into the coating, and erosion, due to particle impacts on the surface. It was found that swelling was dominant initially, seen as a DFT increase, whereafter erosion caused a steady decrease in thickness. The drop in coating DFT will eventually cause the coating to fail, and the area with highest DFT loss rate, will determine the coating lifetime.

In future work, similar experiments will be conducted at conditions close to a full-scale agitated leaching tank, and the effects of acid exposure combined with particle erosion will be investigated with regard to coating performance.

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